METHOD AND SYSTEM FOR IMAGE REGISTRATION USING AN INTELLIGENT ARTIFICIAL AGENT

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 15/587,094, filed May 4, 2017, which claims the benefit of U.S. Provisional Application No. 62/338,059, filed May 18, 2016, U.S. Provisional Application No. 62/344,125, filed Jun. 1, 2016, and U.S. Provisional Application No. 62/401,977, filed Sep. 30, 2016, the disclosures of which are herein incorporated by reference in their entirety.

BACKGROUND OF THE INVENTION

[0002] The present invention relates to registration of medical images, and more particularly to computer-based automated medical image registration using an intelligent artificial agent.

[0003] Medical image registration is an important technology that enables image guided therapy, automated diagnosis imaging, and machine-driven image understanding. The goal of image registration is to recover correspondences between two or more medical images, which can be acquired from different patients/objects, the same patient at different time points, different medical imaging modalities, etc., in order to align or fuse the images. The aligned images can provide important information in various applications. For example, the aligned images can be used to guide minimally invasive therapy by fusing pre-operative volume scans (e.g., MRI) with interventional imaging (e.g., DynaCT or fluoroscopy), or to provide complimentary diagnostic information (e.g., co-registration of cardiac ultrasound and MRI for joint function, flow and substrate analysis) or longitudinal analysis (e.g., radiotherapy monitoring through longitudinal CT scans). Due to the vast range of applications to which image registration can be applied, it is challenging to develop a general image registration method that works robustly for all uses.

[0004] Image registration problems are typically treated as optimization problems in which a generic matching metric (e.g., Mutual Information, Cross Correlation, etc.) is defined to measure the similarity of image pairs to be registered, and transformation parameters between the two images (e.g., rigid body, affine, deformable) are then estimated by an optimizer (e.g., Simplex, Powell, trust region optimization, etc.) via maximization of the defined matching metric. To work robustly, such optimization-based image registration methods typically require extensive hand-crafted engineering for individual registration tasks by incorporating prior knowledge about the specific anatomies, imaging modalities and expected artifacts, or workflows at hand. One reason for this is that a generic matching metric does not guarantee a good representation of the accuracy of the alignment of the data at hand for all use cases, in all circumstances. That is, the global maximum of the matching metric does not necessarily correspond to the correct alignment of the images, for example when the data is noisy, partially occluded, or with drastic different appearances due to different imaging physics. Therefore, the hand-crafted engineering of the matching metric is often required for the specific registration task, for example, by introducing a task-specific region-of-interest (ROI) or calculating hand-crafted features. In addition, a generic matching metric is often non-convex for a given registration task and generic optimizers typically perform poorly on non-convex optimization problems. To avoid being trapped into local minima, prior knowledge is often incorporated to develop optimization schemes for specific registration tasks, for example by prior knowledge-driven initialization/seeding, hierarchical optimization or application specific regularizers.

BRIEF SUMMARY OF THE INVENTION

[0005] The present invention provides methods and systems for registration of medical images using an intelligent artificial agent. Embodiments of the present invention provide artificial intelligent agents that learn registration tasks from training data, and achieve better and better registration results as more data are used for training.

[0006] In one embodiment of the present invention, a current state observation of an artificial agent is determined based on a plurality of medical images and current transformation parameters. Action-values are calculated for a plurality of actions available to the artificial agent based on the current state observation using a machine learning based model trained based on a plurality of registered training images, wherein the plurality of actions correspond to predetermined adjustments of the transformation parameters. An action having a highest action-value is selected from the plurality of actions and the transformation parameters are adjusted by the predetermined adjustment corresponding to the selected action. The determining, calculating, and selecting steps are repeated for a plurality of iterations, and the plurality of medical images are registered using final transformation parameters resulting from the plurality of iterations.

[0007] The machine learning based model used to calculate the action-values based on the current state observation may be a trained deep neural network (DNN). The trained DNN may be trained to predict action-values for the plurality of actions based on a plurality of training image pairs with known ground truth transformation parameters using reinforcement learning in which, for each training image pair, a reward for each action of the plurality of actions at a given state is used to train the DNN to learn an optimal registration policy. The trained DNN may be trained using supervised reinforcement learning, in which the reward for each action of the plurality of actions at a given state is directly calculated based on a decrease in a geodesic distance between the transformation parameters at the given a state and the ground truth transformation parameters for the training image pair resulting from applying the action. The plurality of training image pairs may include training image pairs synthetically generated by artificially de-aligning other training image pairs using randomly generated perturbations to the ground truth transformation parameters of the other training image pairs. The plurality of training image pairs may include training image pairs synthetically generated from other training image pairs to provide dense sampling close to the ground truth transformation parameters by co-deforming the other training image pairs by randomly generated affine transformations within a range of the ground truth transformation parameters. The plurality of training image pairs includes training image pairs synthetically generated by artificially altering image appearance of other training image pairs using synthetic image generators.